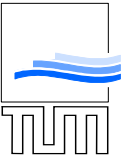


Litoral bottom mapping and water constituent retrieval in lakes using APEX data, the bio-optical model BOMBER and submersed artificial surfaces

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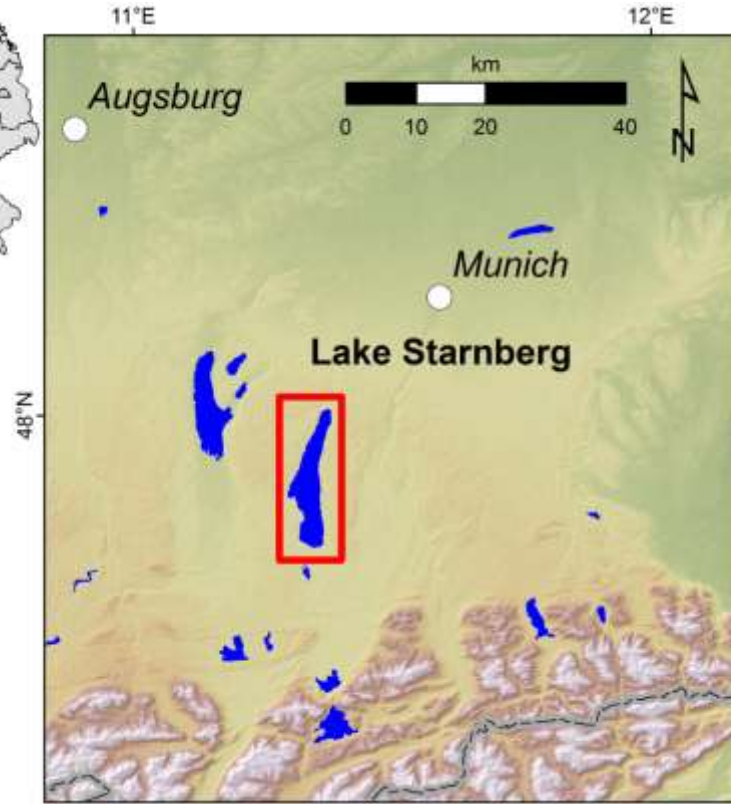
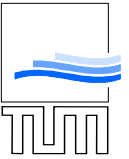
- 1. Aims and objectives**
- 2. Study area and APEX data**
- 3. In situ measurements**
- 4. Simulated data**
- 5. Methods**
- 6. Results**
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1. Aims and objectives



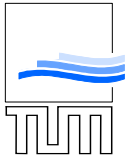
- Stable derivation of optical active water constituents (Inherent optical properties – IOPs) requires well knowledge about the bottom reflectance
- Information about IOPs is essential for the correction of the water column to achieve bottom albedo which are used in further classifications
- We are focused on mapping two invasive submersed macrophytes (*Najas marina* and *Elodea nuttallii*)
- In an experimental approach, the use of artificial littoral coverage is evaluated to retrieve water properties (IOPs) and bottom properties (Reflection, bottom depth)

2. Study Area and APEX data



APEX data was acquired on 10/09/2011 covering the western shore of Lake Starnberg

3. In situ measurements

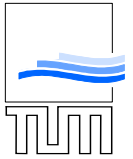


- Two silo-foils (10 x 50 meters) were spread over the litoral bottom covering depths from 0.5 to 16 meters to create artificial surfaces with known reflectance (measured with ASD)
- One foil was layed with the white side up, the other with the black side faced upwards
- Above the foils, spectrometric measurements were made using three submersible RAMSES (TriOS) sensors



- One radiance (ARC; FOV=7°) and two irradiance (ACC; FOV=180°) sensors
- 320-950 nm, spectral sampling 3.3 nm
- Operated simultaneously for recording the upwelling radiance (L_u), the upwelling irradiance (E_u) and the downwelling irradiance (E_d) in water

3. In situ measurements

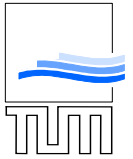


- Measurements were performed over three deep (9 m, 6m, 4m) and two shallow (0.5 m) areas above each foil in different depth intervalls (20 iterations)
- Depth and position were controlled using an integrated pressure sensor (RAMSES) as well as a stereo-photosystem attached to the sensors
- The depth difference between the entrance optics of E_d and L_u/E_u were taken into account in the further processing





4. Methods - BOMBER



- The bio-optical model BOMBER (Giardino et al., 2012) performs least square optimization for the retrieval of best fitting IOPs and bottom properties (unimixing of 3 bottom albedo and depth)

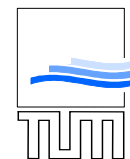
$$\begin{aligned} a &= a_{water} + a_{CHL} + a_{SPM} + a_{cDOM} \\ b &= b_{water} + b_{CHL} + b_{SPM} \\ u &= \frac{b}{a + b} \\ r_{rs}^{\infty} &= (0.084 + 0.170u)u \end{aligned}$$

Total absorption and backscattering coefficients

Reflectance of deep-water only depends on IOPs

- The ENVI add-on BOMBER contains deep and shallow water models for the retrieval of water and bottom properties from remotely sensed data (atmospherically corrected)
- For the shallow model, the underwater Sun Zenith angle and possible bottom reflectances for unmixing has to be defined

4. Methods – BOMBER shallow model



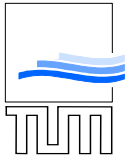
- In the shallow water model of Lee et al. (1999), the apparent reflectance is a sum of contribution of the water and the bottom (lowered by the attenuation of E_d , L_u (water) and L_u (bottom))

$$r_{rs} = r_{rs}^{\infty} \left(1 - \exp \left\{ - \left[\frac{1}{\cos(\theta_w)} + 1.03(1 + 2.4u)^{0.5} \right] (a + b)H \right\} \right) + \frac{1}{\pi} \rho \exp \left\{ - \left[\frac{1}{\cos(\theta_w)} + 1.04(1 + 5.4u)^{0.5} \right] (a + b)H \right\}$$

contribution of water

bottom contribution

5. Simulated data



- To test the performance of the optimization procedure for different water types, simulated spectra were created using random values for IOPs and depth (created with python 2.7):

CHL: 1.0 – 5.0, startvalue for inversion: 2.0

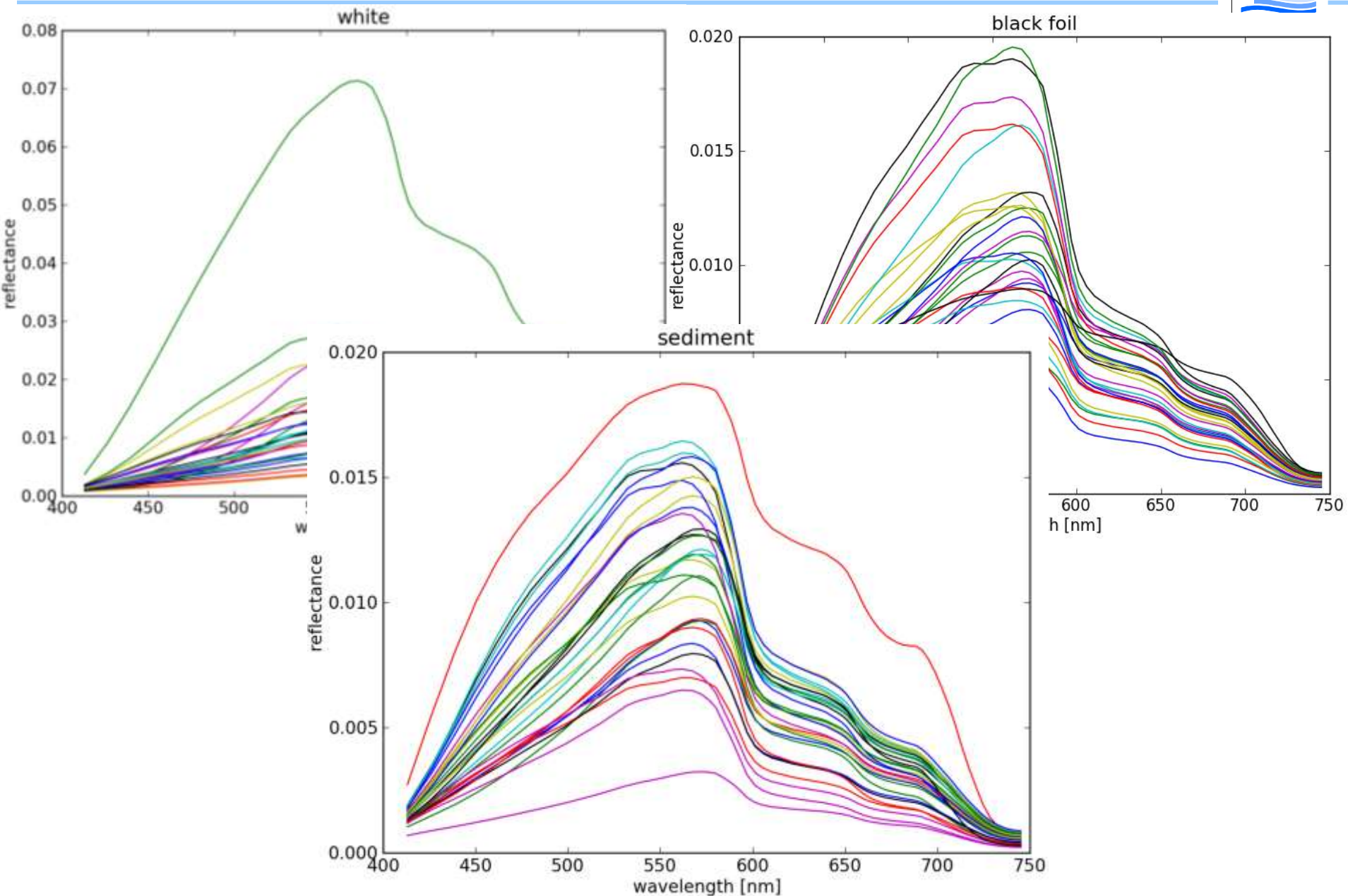
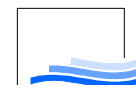
SPM: 1.0 – 5.0, startvalue for inversion: 2.0

cDOM: 0.2 – 0.7, startvalue for inversion: 0.4

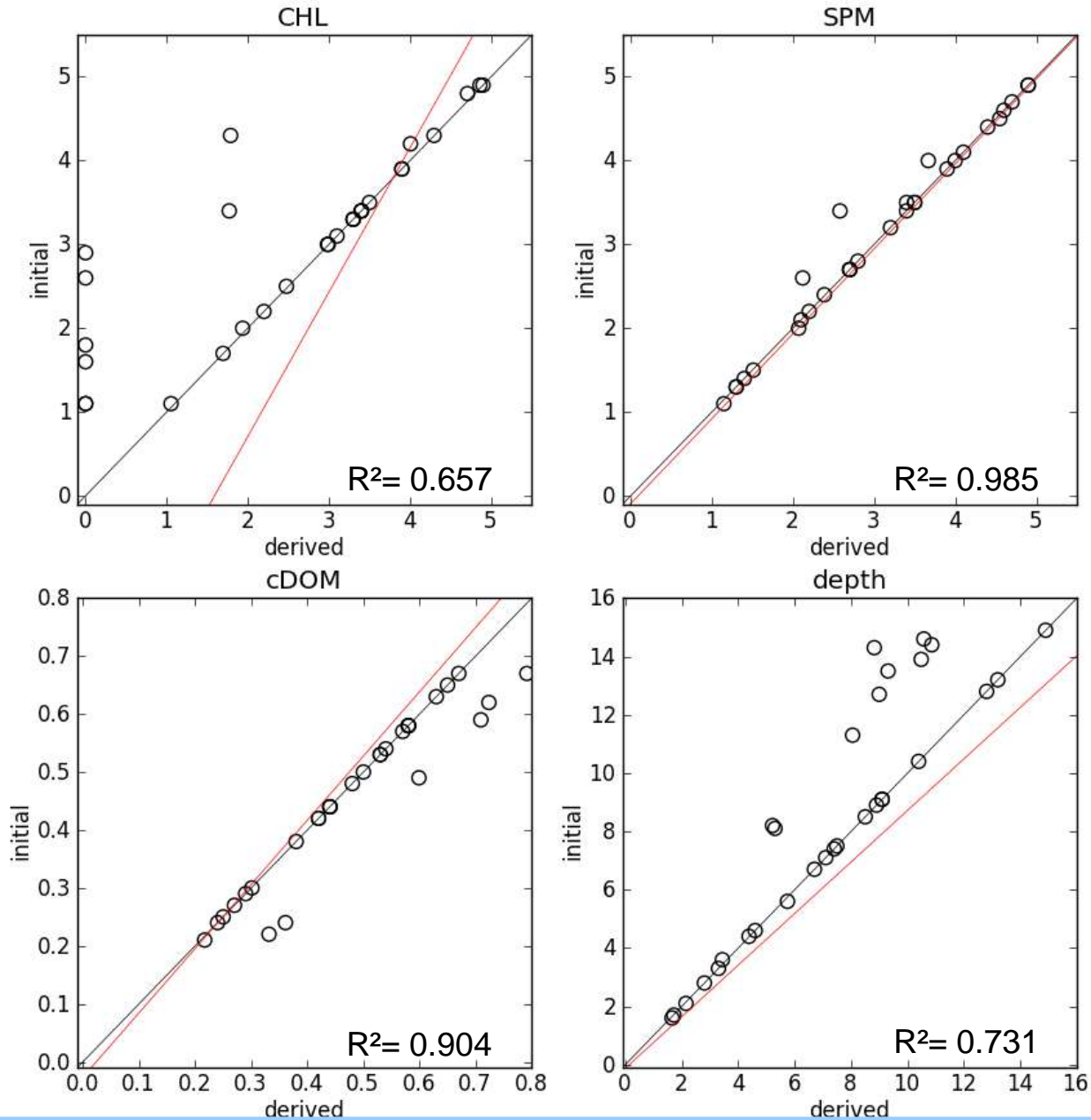
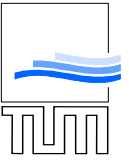
Depth: 0.5 – 15, startvalue for inversion: 4.0

- For each bottom type (white foil, black foil and bare sediment) 30 reflectance spectra were calculated with 1nm resolution and rescaled to the spectral resolution of APEX (first 70 bands)

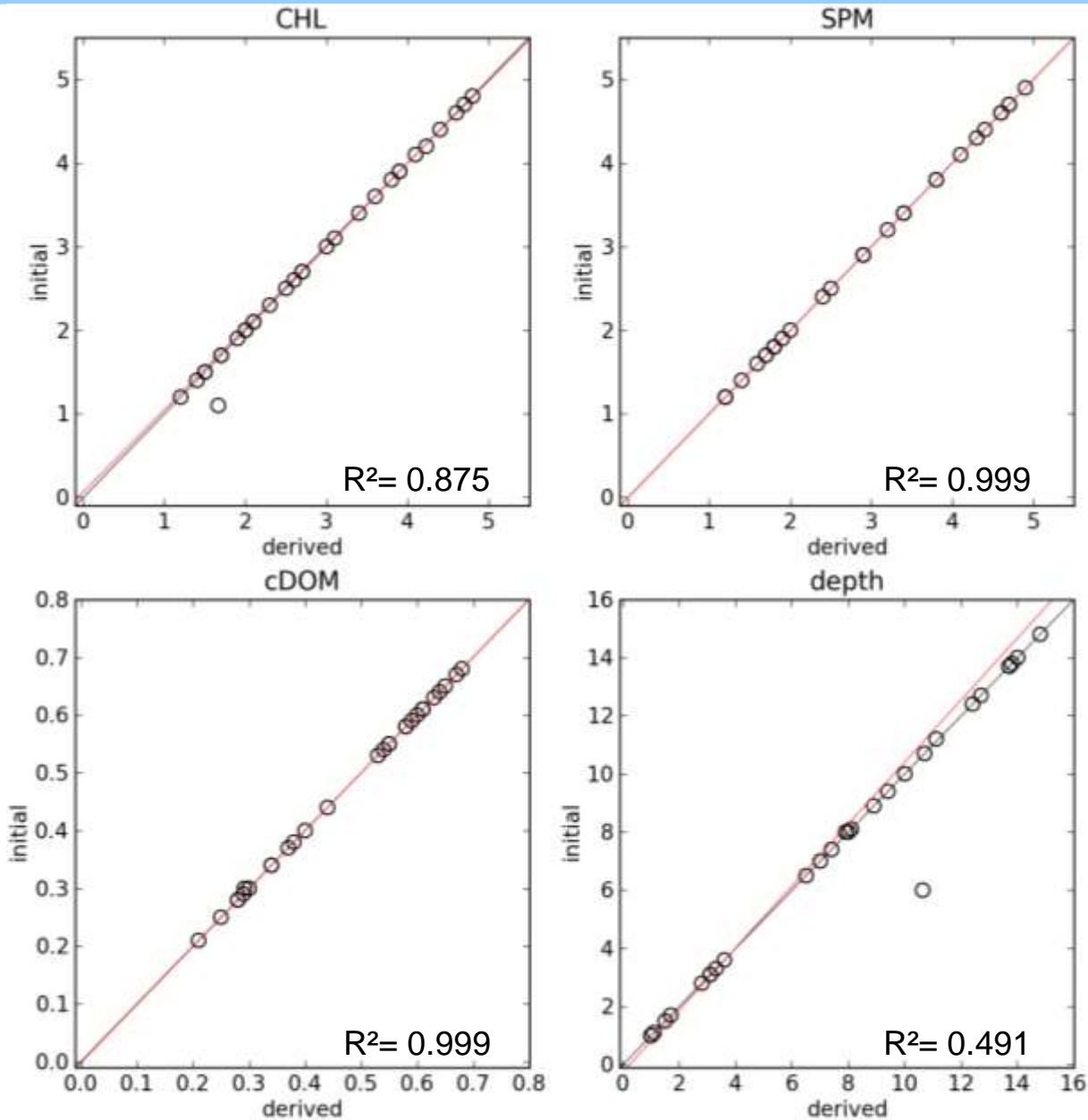
5. Simulated data



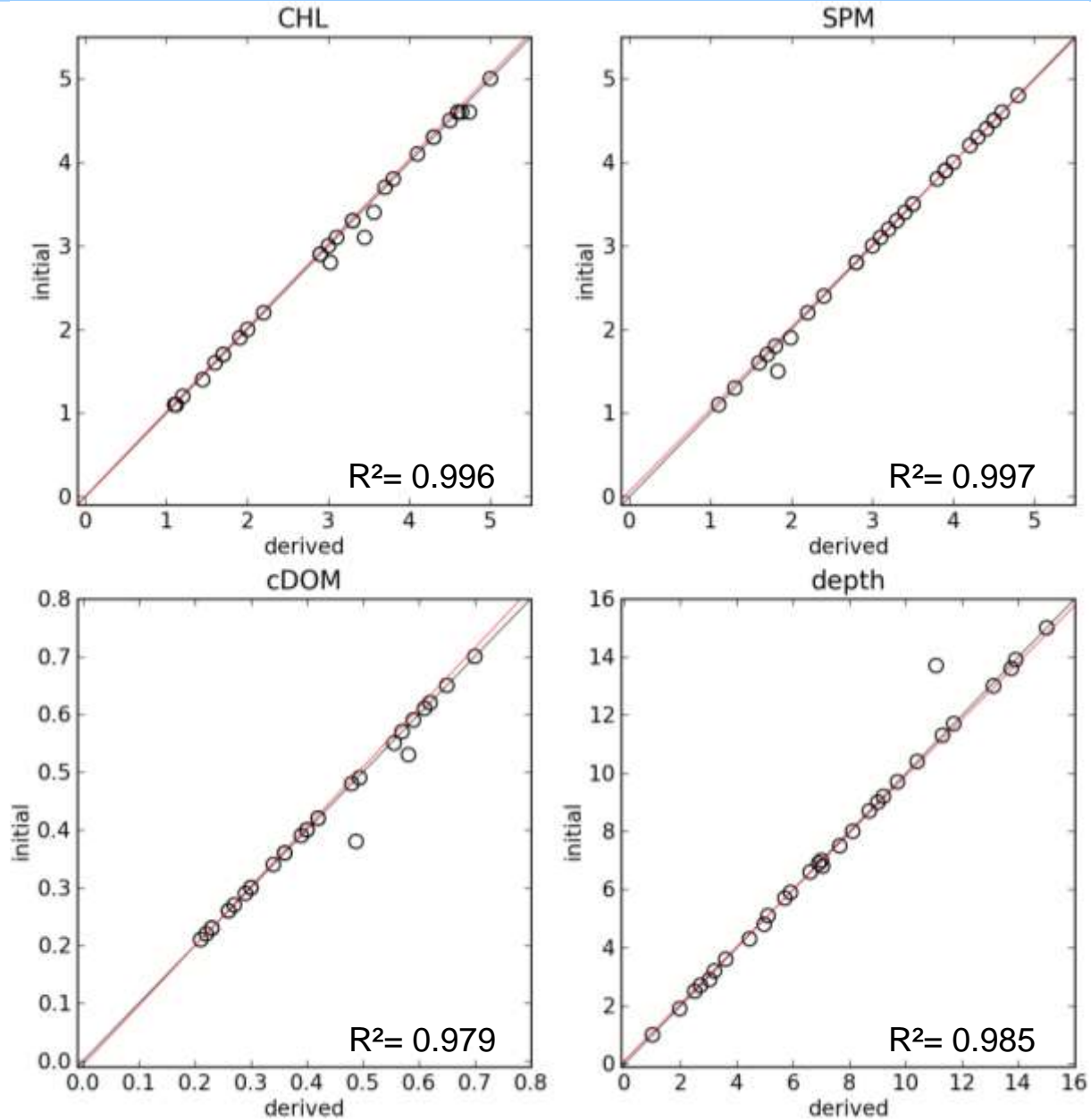
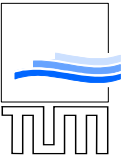
6. Results: simulated APEX data (white)



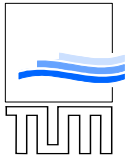
6. Results: simulated APEX data (black)



6. Results: simulated APEX data (sediment)



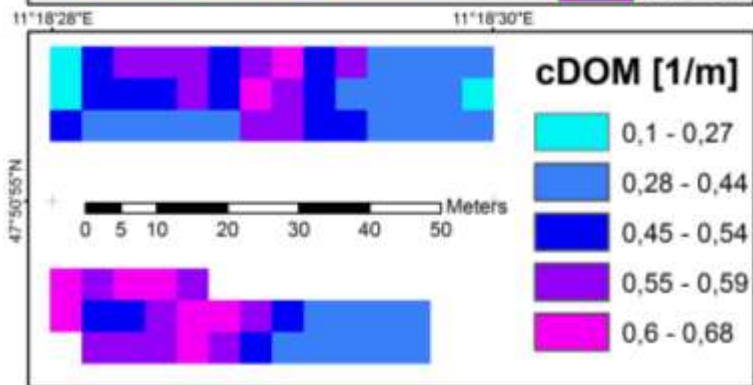
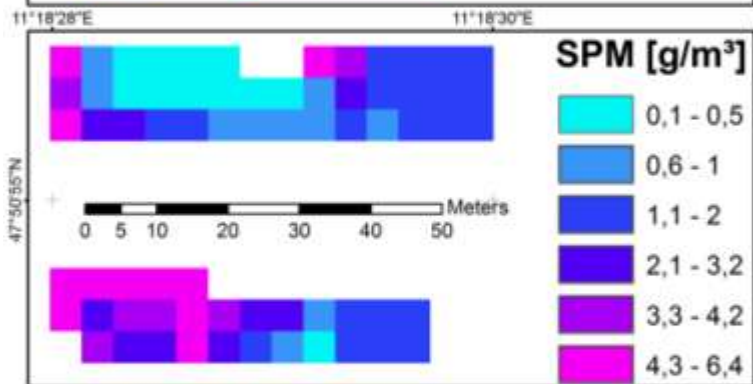
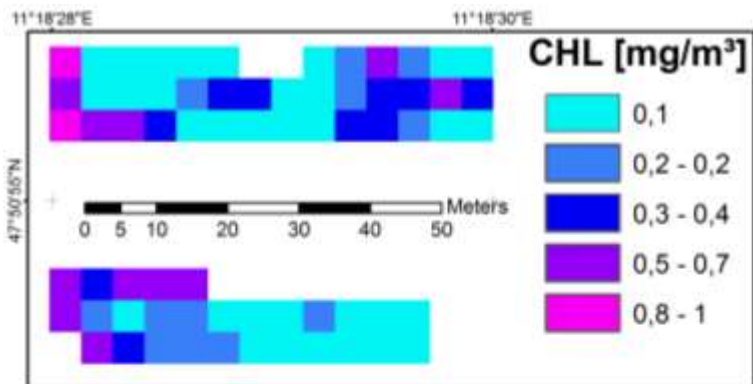
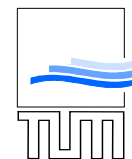
6. Results: in situ RAMSES measurements



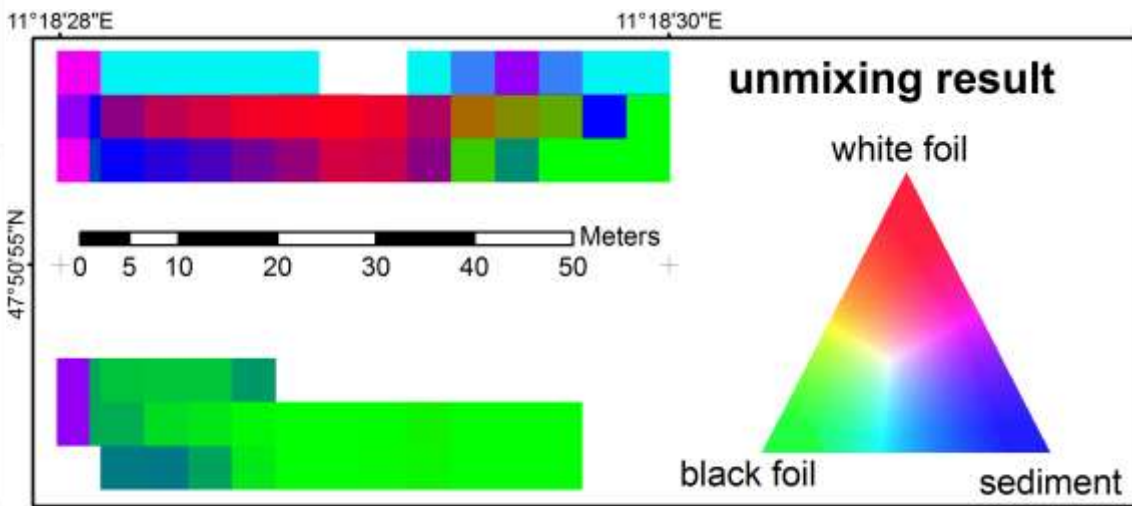
Results of the Lee-model inversion for the measurements performed at the highest sensor position (i.e. water depth = 0.4 m)

	black foil			white foil		
bottom depth (real) [m]	8	5.5	3.4	8.1	5.6	3.3
bottom depth [m]	4.8 ± 0.2	5.4 ± 0.7	4.5 ± 2.2	12.2 ± 0.4	5.8 ± 1.8	3.2 ± 0.1
CHL [mg m^{-3}]	0.8 ± 0.1	0.8 ± 0.1	1.2 ± 0.4	3.5 ± 0.2	1.5 ± 2.1	3.1 ± 0.7
SPM [g m^{-3}]	1.4 ± 0.2	1.5 ± 0.3	1.7 ± 0.5	1.4 ± 0.2	1.1 ± 0.3	3.2 ± 0.7
cDOM [m^{-1}]	0.4 ± 0.0	0.4 ± 0.0	0.5 ± 0.0	0.4 ± 0.0	0.4 ± 0.1	0.4 ± 0.0

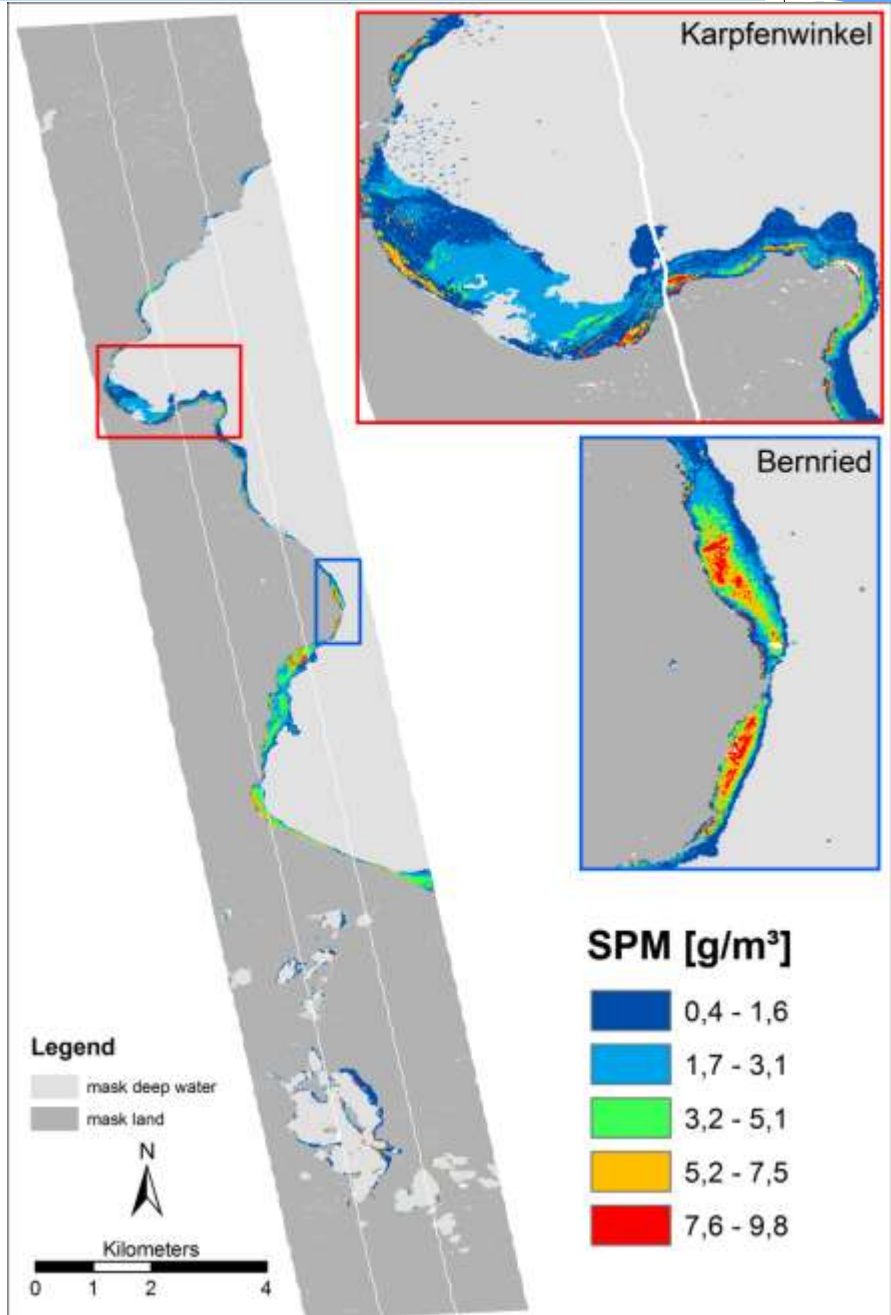
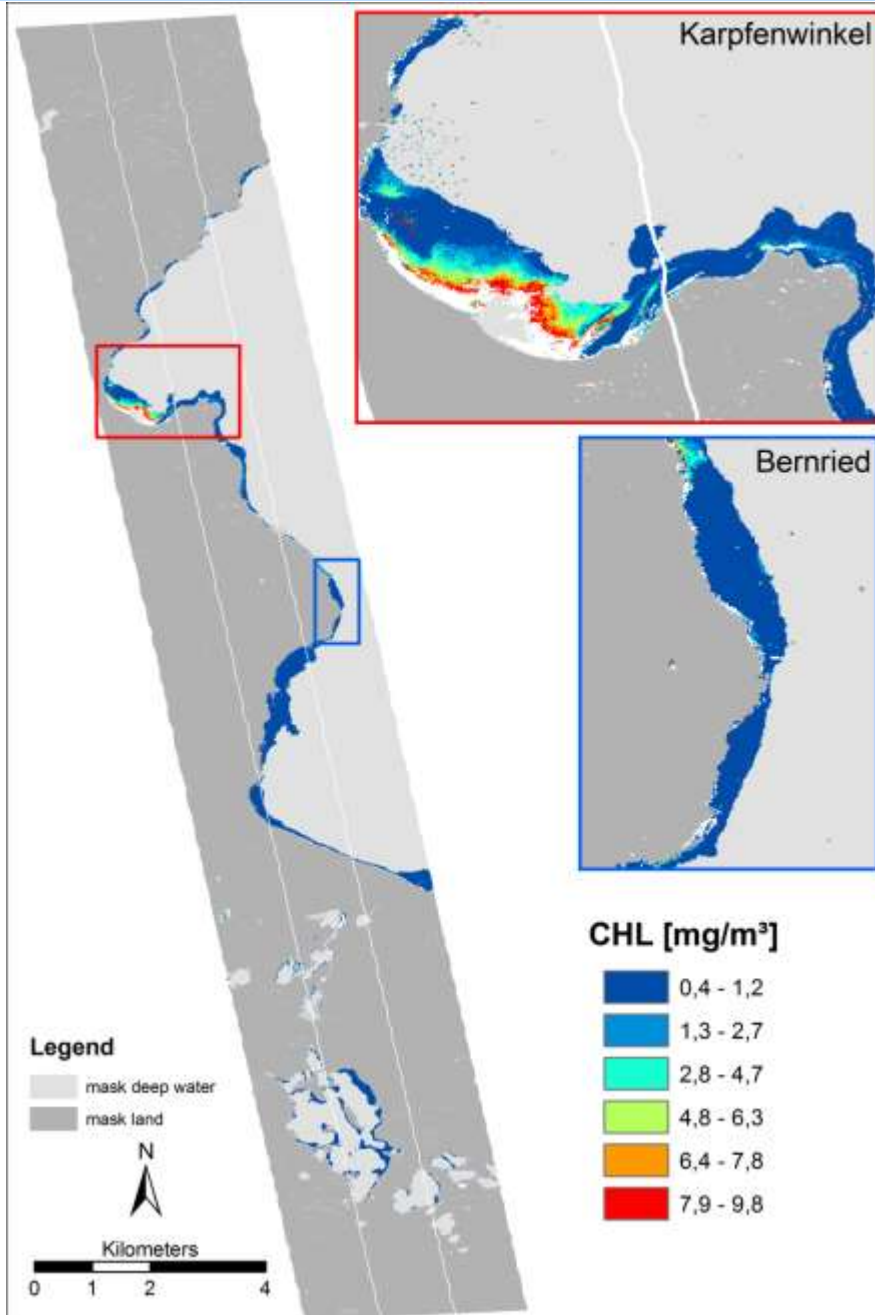
6. Results: APEX inversion above foils



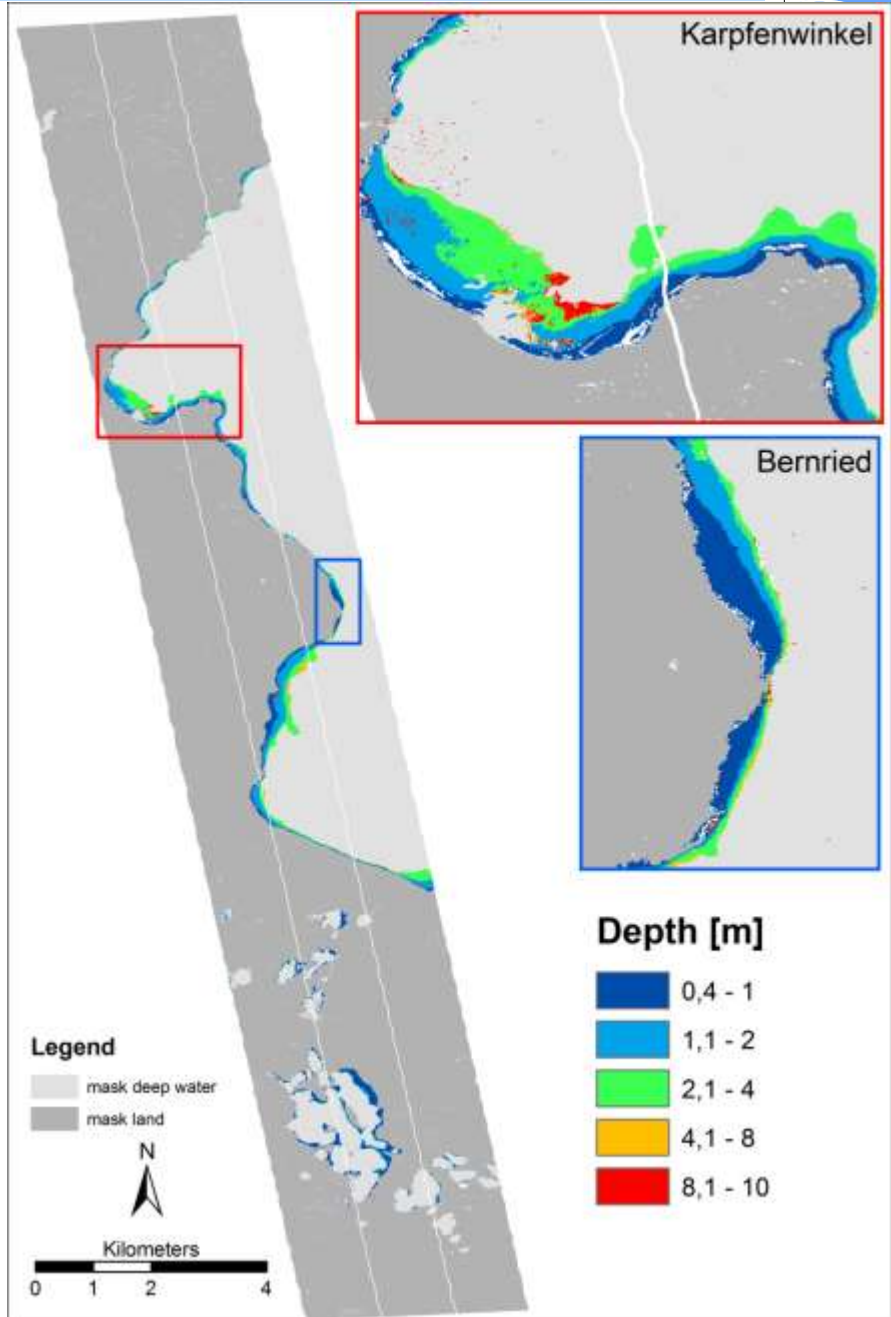
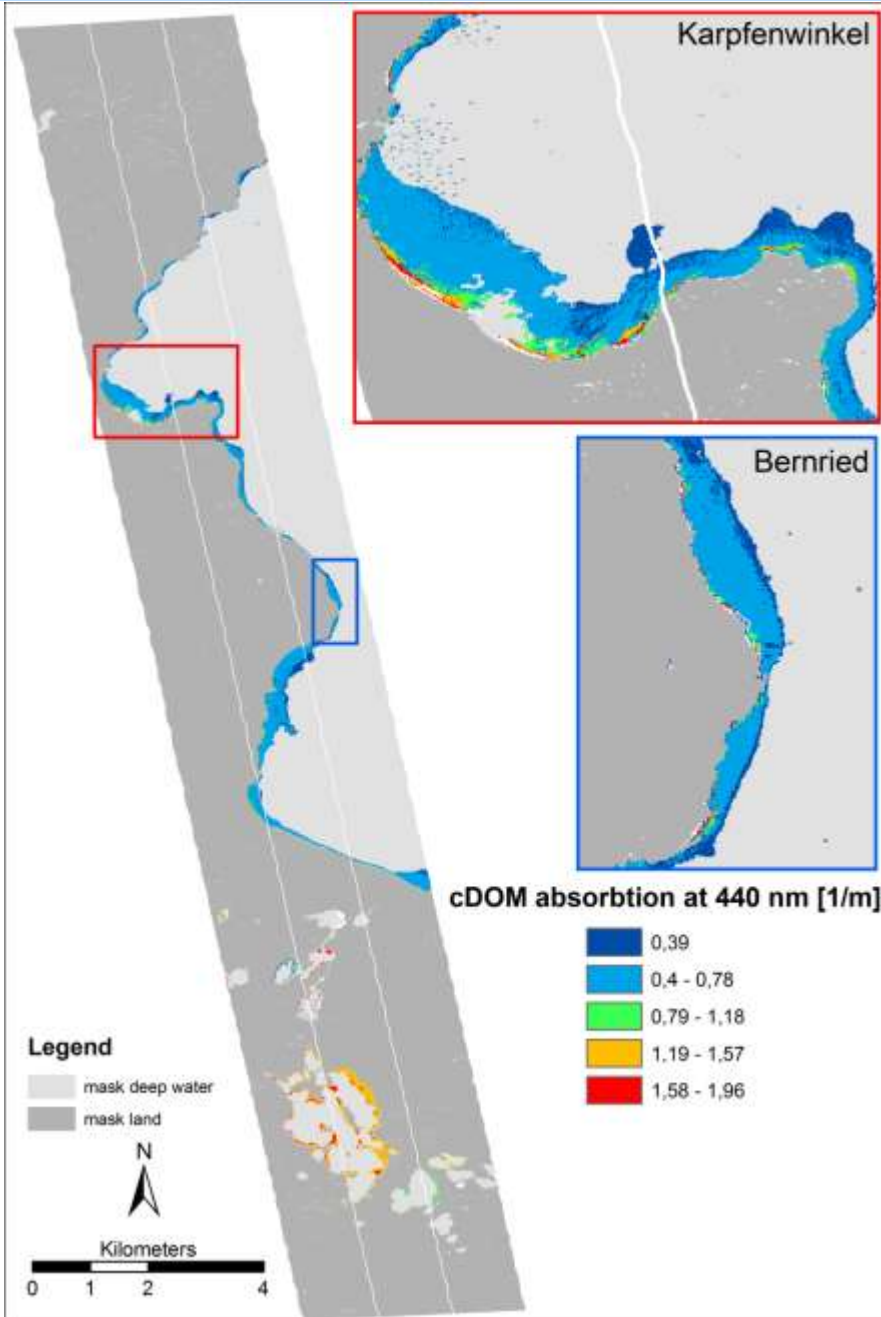
	ROI white foil			ROI black foil		
	MIN	MAX	MEAN ± STDV	MIN	MAX	MEAN ± STDV
bottom depth [m]	0.6	100.0	11.7 ± 25.6	0.6	100.0	15.2 ± 30.5
CHL [mg m ⁻³]	0.0	24.8	0.98 ± 4.21	0.0	0.5	0.17 ± 0.16
SPM [g m ⁻³]	0.0	23.5	2.04 ± 3.9	0.1	6.5	2.98 ± 1.6
cDOM [m ⁻¹]	0.1	0.6	0.45 ± 0.12	0.3	0.7	0.52 ± 0.1



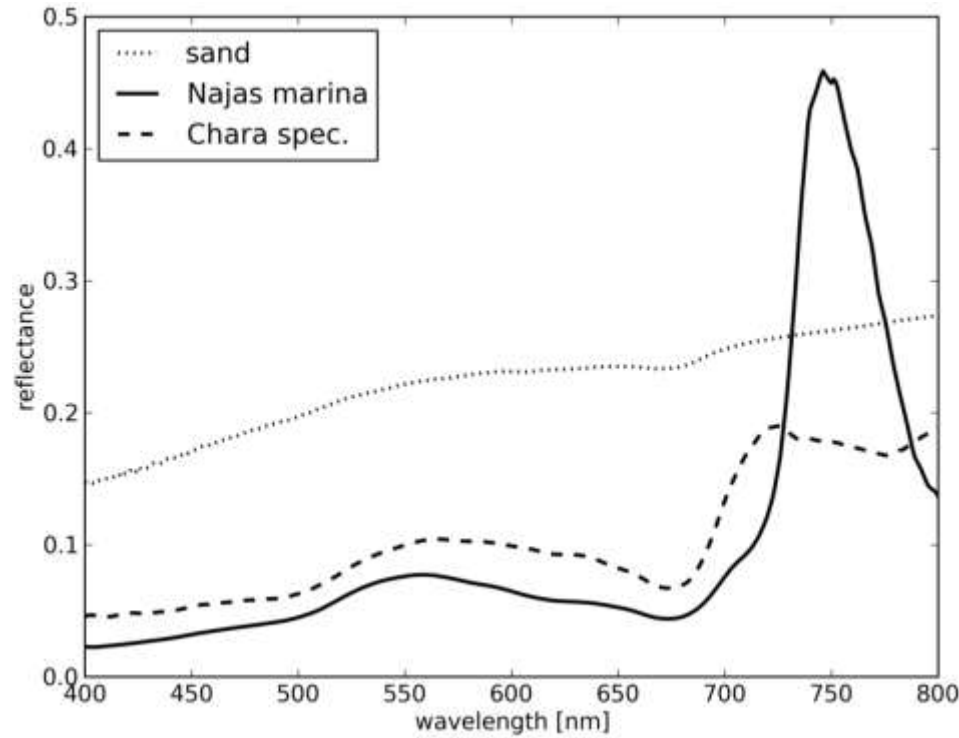
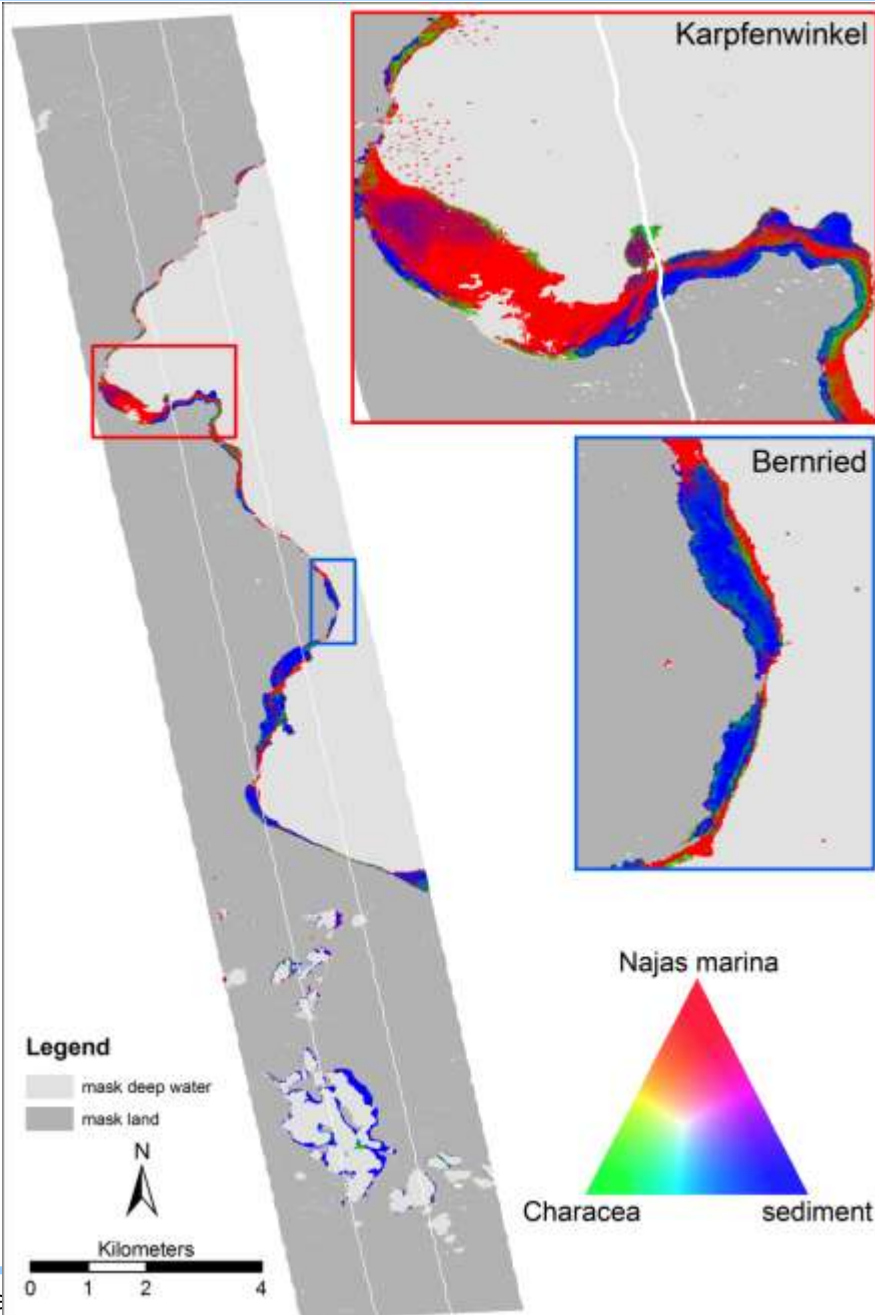
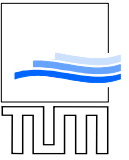
6. Results: APEX whole scene - shallow



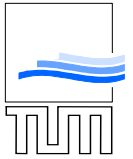
6. Results: APEX whole scene - shallow



6. Results: APEX whole scene - shallow



4. Conclusions



- Best results for the simulated data were achieved with natural reflectors
- Despite the very high contribution to the overall reflectance of the white foil, the derivation of water constituents and the depth show large uncertainties
- The black foil can be regarded as an artificial deep water area due to nearly wavelength-independent reflectance (~5%) behaviour and provides good results for the inversion of in situ data, as well as airborne APEX data
- The Model BOMBER performed very good, showing IOP values similar to the in situ derived concentrations
- Validation work has to be conducted in terms of species identification and depth derivation

Thank You!

Questions?

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